User Interface by Virtual Shadow Projection

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Abstract: This paper introduced a user interface based on virtual shadow derived by projector for Spatial Augmented Reality (SAR) environment. Shadow is a daily phenomenon in our daily life and may contribute to build an effective and intuitive connection between physical and digital world. Taking advantage of spatial and optical characteristics of shadow, user can realize remote interaction for ubiquitous interface. The prototype system is implemented and adaptive image processing algorithms for shadow are proposed. The authors has demonstrated in this paper that shadow has possibility to realize simple but effective interface between human and computer systems, which may yield to many useful applications without massive device resources.

Keywords: Human Interface, Gesture Recognition, Spatial Augmented Reality

1. INTRODUCTION

Now displays have become so ubiquitous that every physical surface can act as interactive display [1, 2]. Projector-camera systems represent an effective approach towards constructing an indoor environment with ubiquitous display capabilities without massive equipment resources. Mouse, keyboard and monitor build up traditional input and visual feedback loop for desktop computer systems. New and suitable human-computer connection should be discussed and explored for new spatial relationship between projected display and user in a larger indoor area.

We proposed a user interface based on shadow projection and gesture recognition for indoor SAR environment (Spatial Augmented Reality [3]). Shadow is a common phenomenon where there is light source. It is possible to use shadow as an effective and intuitive connection between our physical world and digital world [4]. We also take advantage of shadow's optical characteristics to realize remote interaction for ubiquitous user interface. We believe this novel proposal is economical. This system doesn't require any special and expensive equipment, and compared with some applications based on mobile and wearable devices [5, 6, 7]. It also frees us from troubling body burden; we also believe this system is intuitive since our daily experience is integrated. Compared with mouse cursor as a visual feedback corresponding to mouse movement, shadow itself is a more natural and intuitive visual feedback corresponding to body movement.

The key challenge in system implementation is to find the adaptive image processing algorithm to fit in the spatial and optical features of shadow. Since the projected shadow is not the real shadow but the artificial one, any mistracking and processing lag may result in unnatural feeling. We propose several solutions for special characteristics of shadow. First, the size of shadow changes significantly according to the distance between user and light source. Instead of mask with fixed size, scalable mask whose size can be adjusted in real time according to the size of shadowed area is applied to track the point of interest such as fingerpoint. Second, the shadow image consists of only two areas, shadow area and background area. With that feature, we can skip the white blank background area and process only shadow area. With the improved algorithm, there is obvious increase in process speed and the system lag was greatly reduced. Third, shadow is a planar image which lacks depth information. Rather than merely considering hand/body shape in current frame as gesture input, we propose gesture recognition algorithm on time sequence to realize more functions. The previous gesture statuses were stored in memory. The system determines output together with current gesture status and previous gesture statuses. Experiments showed the adaptive algorithm improved the effectiveness and efficiency of the system.

In Chapter 2, system overview is given. In Chapter 3, system implementation is explained with details. In Chapter 4, practical applications are described with two examples. Finally, conclusion is made in Chapter 5.

2. SYSTEM CONFIGURATION

As shown in Fig.1, the system consists of user, computer, IR light source, IR camera and projector. IR camera and projector are mounted on the ceiling while IR light source is behind the user. The body shadow is projected onto the wall by the IR light source, and the IR camera captures this invisible IR shadow. After processing, the artificial shadow is projected onto the wall by the projector.

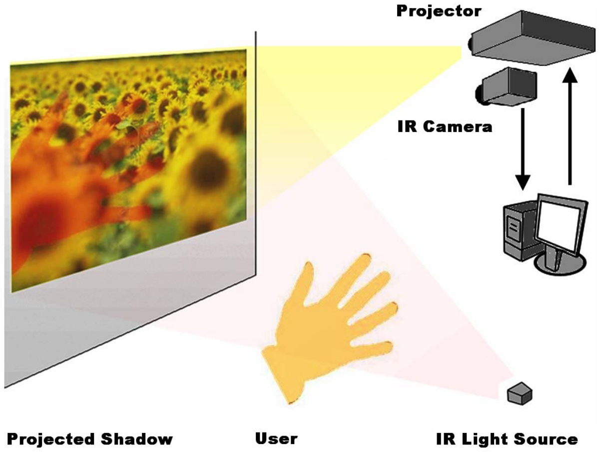

Fig. 1 System overview

Compared with real shadow, artificial shadow is more flexible in:

- Pattern / Color, as shown in Figure 10 (e)
- Transparency, as shown in Figure 10 (f)
- Overlapping layer, as shown in Figure 10 (g)

Spectator's experience is an important issue. Some tasks require less user attention to the shadow's appearance such as presentation while some tasks require more such as art application. The appearance of artificial shadow can be adjusted to fit with different requirements. So this is the reason why we adopt artificial shadow rather than real visible shadow.

3. VIRTUAL SHADOW CREATION

3.1 Input processing

Different lighting conditions results in different algorithms. In ideal lighting condition in experimental environment, the quality of raw input image is fine as shown in Fig.2. In such case, normal binarization is enough to get the expecting result. However, if the light source has spot light shading, the problem becomes complicated. We considered that a more robust algorithm is necessary for applications under various lighting conditions.

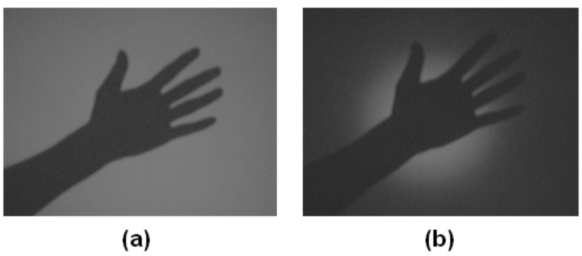

Fig. 2 Lighting condition: (a) ideal lighting condition in experimental environment; (b) normal lighting condition with spotlight effect

As shown in Figure 3. Uniform Blocking is the first step. This step involves dividing the images into uniform blocks for processing. Typically size are 16x16 blocks if the merge-split algorithm was to be used. The second step is Split and Merging. A threshold determines which blocks can be merged into a single block and which blocks can be split into smaller blocks based on the difference between the maximum and minimum intensities in each block. This process is done recursively until, no blocks satisfy the criteria to be split or merged. The third step is Region Growing. The mean values of the blocks are used to determine which blocks should be merged. The last step is Smoothing. The noise or smaller regions are smoothed into larger region. For shadow image, this process is done recursively until there are only two regions: background and shadow.

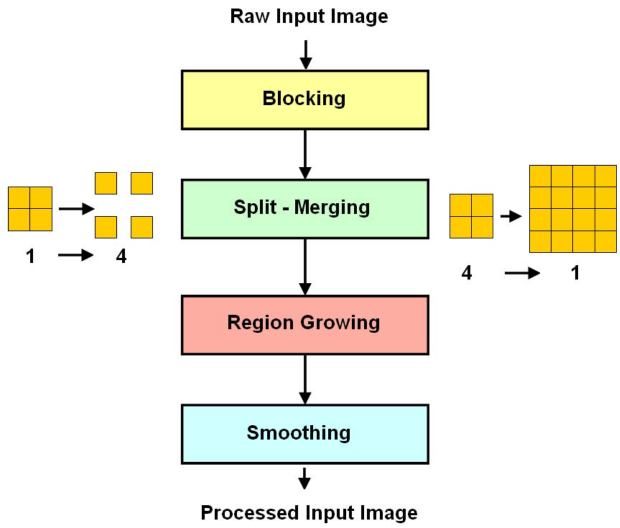

Fig. 3 Processing the input image

3.2 Finger point tracking algorithm

Most of tracking mask operators based on hand/finger shape require much CPU resource and causes significant lag when the image resolution is high. We propose an improved algorithm to increase the processing speed. There are two useful features of hand shadow. One feature is that a big proportion of a shadow image is white blank background, so such background can be ignored in processing. Another feature is that finger point is a point with least surrounding shadowed area than any other parts of hand. Based on these two features, our tracking algorithm can be simplified into two questions:

- 1st question: Is the center of a mask shadowed? If yes, go to the 2nd question; if no, just skip this pixel.
- 2nd question: What's the shadowed area inside this mask? If the area is smaller than current best answer, then replace current best answer with this one.

Figure 4 shows three different situations and only the first one (a) represents the right finger point. The middle one (b) is wrong for it has no shadowed center. The right (c) one is wrong for it doesn't get the least shadowed area.

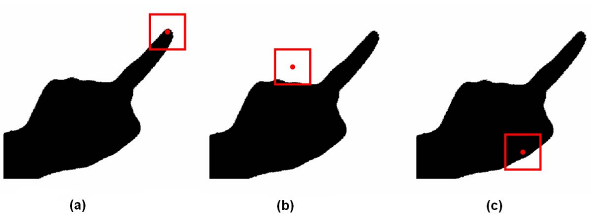

Fig. 4 Samples of finger tracking: (a) is the only correct result; (b) and (c) are incorrect results.

The size of the tracking mask is adjusted in real time according to the size of shadowed area. For multiple finger points tracking, the first best answer will be labeled the first finger point. The labeled finger point will not be included in the next round so that other fingers can be detected, shown in Fig.10 (d).

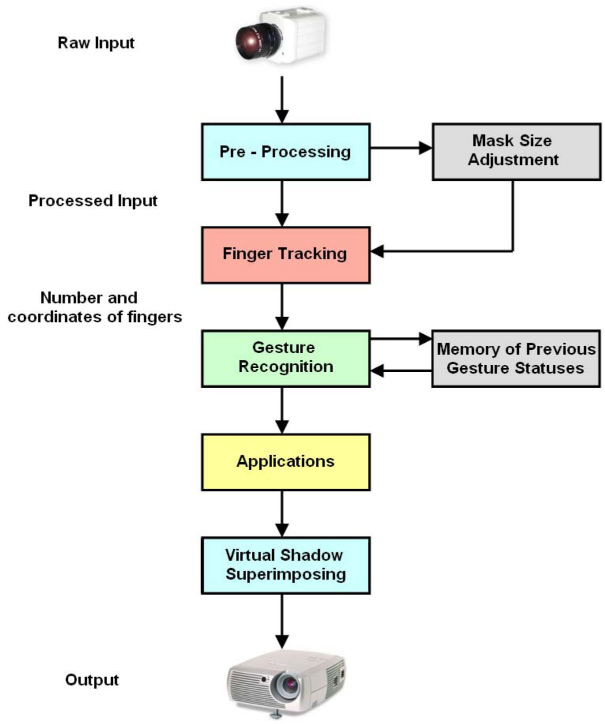

Fig. 5 Image processing pipeline

3.3 Gesture recognition on time sequence

We mentioned that two-dimensional shadow lacks depth information and can only represent limited meanings for different functions. Gesture recognition on time sequence can further exploit our rich hand/body gestures to represent for various functions. So same gesture shapes may represents different meanings if they have different time patterns.

Figure 6 gives a simple example, showing that same gesture shapes representing different functions. Figure 6 (a) shows a one finger gesture. The lasting of this status decides the corresponding function. (b) shows the case that the gesture represents for number “1” when (a) lasts less than 15 frames (frame/33ms). (c) shows the case of painting. The painting function will be triggered only when (a) lasts for more than 50 frames.

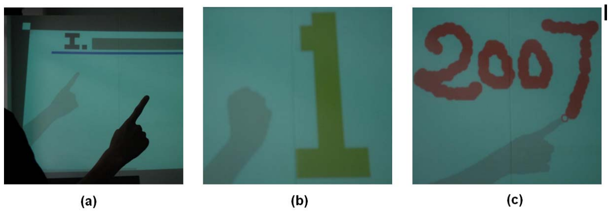

Fig. 6 Examples of same gesture appearance with different functions on time sequence. (b) represents number “1”; (c) represents shadow painter

4. APPLICATIONS

We implemented the prototype system with many different functions. Figure 7 shows the ‘Shadow Painter’ application derived from real visible shadow. The user can actually use his/her fingerpoints to draw pictures on the desk surface. Figure 8 is about ‘Click and Drag’ application derived from IR light source, showing that shadow can realize the basic mouse functions in distance. This application also demonstrates that artificial shadow is flexible in color and transparency. Figure 9 shows ‘Presentation Assistant’ application. The presenter uses his/her hand gestures to forward to next page or back to previous page. Besides, the presenter can draw lines and circles on the wall or his/her presentation purpose. In this application, we can see that the shadow is on a lower image layer which is overlapped by presentation content.

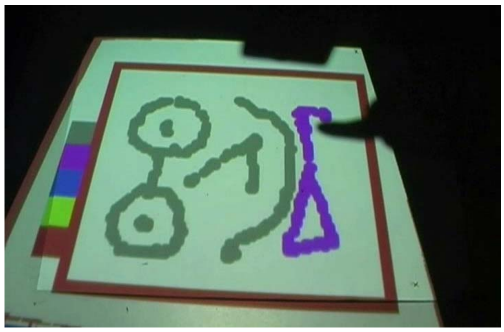

Fig. 7 “Shadow Painter” by real shadow

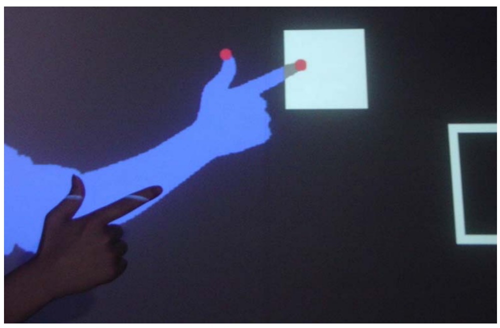

Fig. 8 “Click and Drag” by virtual shadow

Fig. 9 "Presentation Assistant" by virtual shadow

The authors believe that with this framework, the shadow interface concept might spark other application ideas. We concluded the possible applications of the proposed system in the following fields:

- Assistance to presentation based on projector
- Entertainment
- Media art
- Educational interaction in museums
- Touchless interface in hospitals
- Remote control inside intelligent house

5. CONCLUSIONS

In this paper, we introduced a user interface based on capture and projection of our body shadow in indoor SAR environment. We believe this novel interface method is economical and intuitive, which may yield to many useful applications without massive equipment resources.

We implemented the prototype system with adaptive image processing algorithm based on spatial and optical features of shadow. We described in our paper about scalable mask, improved finger tracking method and gesture recognition on time sequence.

The authors have demonstrated that shadow has possibility to realize simple but effective interface between human and computer systems.

REFERENCES

[1] R. Raskar, G. Welch, M. Cutts, A. Lake, L. Stesin, and H. Fuchs, "The office of the future : A unified approach to image-based modeling and spatially immersive displays", In *Proc. ACM SIGGRAPH,* Orlando, FL, 1998.

[2] T.A. Funkhouser and K. Li, "Special issue on Large-Format Display", *IEEE Computer Graphics and Applications*, 20(4), 2000.

[3] Oliver Bimber, and Ramesh Raskar, *Spatial Augmented Reality*, AK Peters, Wellesley, 2004.

[4] H. Ishii, and B. Ullmer, "Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms", *Proceedings of Conference on Human Factors in Computing Systems*, pp. 234-241, 1997.

[5] MacKenzie. I. and Jusoh. D, "An evaluation of two input devices for remote pointing", *Eighth IFIP Working Conference on Engineering for Human-Computer Interaction*, p. 235-249, 2001.

[6] Matveyev, S. and Gobel, M. The Optical Tweezers, "multiple-point interaction technique", *Virtual Reality Software and Technology*, p. 184-188, 2003.

[7] Myers. B., Bhatnagar. R., Nichols. J., Peck. C.H., Kong. D., Miller. R. and Long. C, "Interacting at a distance: measuring the performance of laser pointers and other devices", *ACM CHI Conference*, p. 33-40, 2002.

[8] May.R, "HI-Space: A Next Generation Workspace Environment", *Master's Thesis in Electrical Engineering Computer Science*, Pullman, Washington, Washington State University, 1999.

[9] Koike.H, Y.Sato, et al, "Interactive Textbook and Interactive Venn diagram: Natural and Intuitive Interfaces on Augmented Desk Systems", *SIGCHI*, 2000.

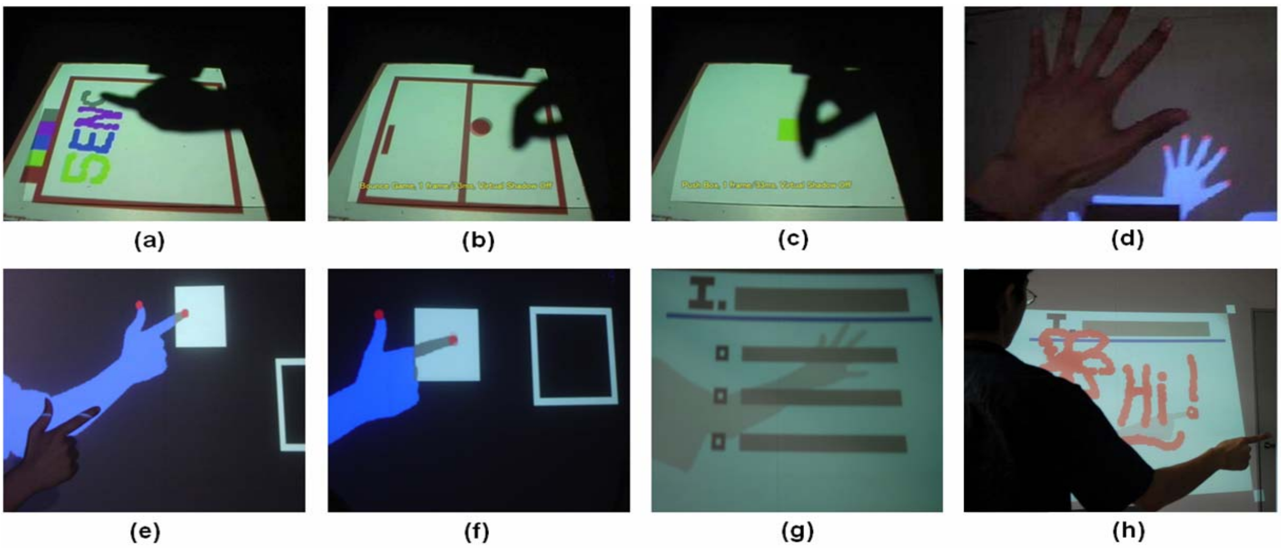

Fig. 10 Applications of user interface by real and virtual shadows. Real shadow applications: (a) drawing, (b) gaming, (c) pushing virtual object; Virtual shadow applications: (d) finger tracking, (e) and (f) clicking and dragging, (g) and (h) interactive presentation.